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UNIVERSITEIT GENT

Environmental Sustainability Assessment of a Microalgae Raceway Pond Treating Wastewater from a Recirculating Aquaculture System

From Upscaling to System Integration

Sophie Sfez[(a)], Sofie Van Den Hende[(b)], Sue Ellen Taelman[(a)], Steven De Meester[(a)], Jo Dewulf[(a)]

(a) Department of Sustainable Organic Chemistry and Technology, Ghent University, Coupure Links 653, B-9000 Ghent, Belgium

(b) Laboratory for Industrial Water and Eco-Technology (LIWET), Faculty of Bioscience Engineering, Ghent University, Graaf Karel de Goedelaan 5, B-8500 Kortrijk, Belgium

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
nwe
INTERREG IVB

EnAlgae
collaborate innovate communicate

Vlaamse overheid

west-vlaanderen
de gedreven provincie

Sustainable Pathways for Algal Bioenergy

Introduction

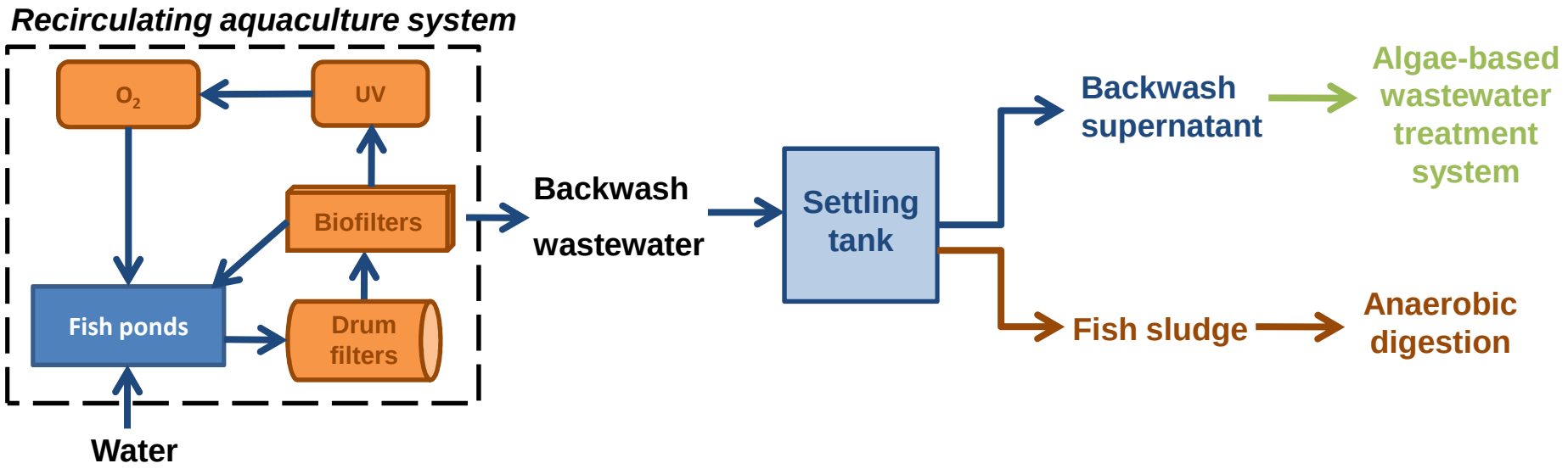
- EnAlgae: INTERREG IVB North West Strategic Initiative (03/2011 – 06/2015)

- 9 pilot scale algae cultivation sites (micro- and macroalgae)

- In Roeselare, Belgium: Algae-based wastewater treatment plant, treating wastewater from a pikeperch recirculating aquaculture systems (RAS)

Introduction

- Aquaculture: fast growing sector competing for freshwater resources
- RASs: promising option to mitigate the environmental footprint of aquaculture systems



- The MaB-floc technology tested in 2013 in Belgium at pilot scale to treat pikeperch aquaculture wastewater from the Aquaculture Research Center of Inagro (Belgium)

Introduction

- MaB-flocs: bioflocculating consortium of bacteria and microalgae
- As they grow, MaB-flocs need to be harvested, delivering a new source of biomass: valorisation as *shrimp feed* and *anaerobic digestion* were tested at pilot scale

→ Industry needs insights to know which direction to take

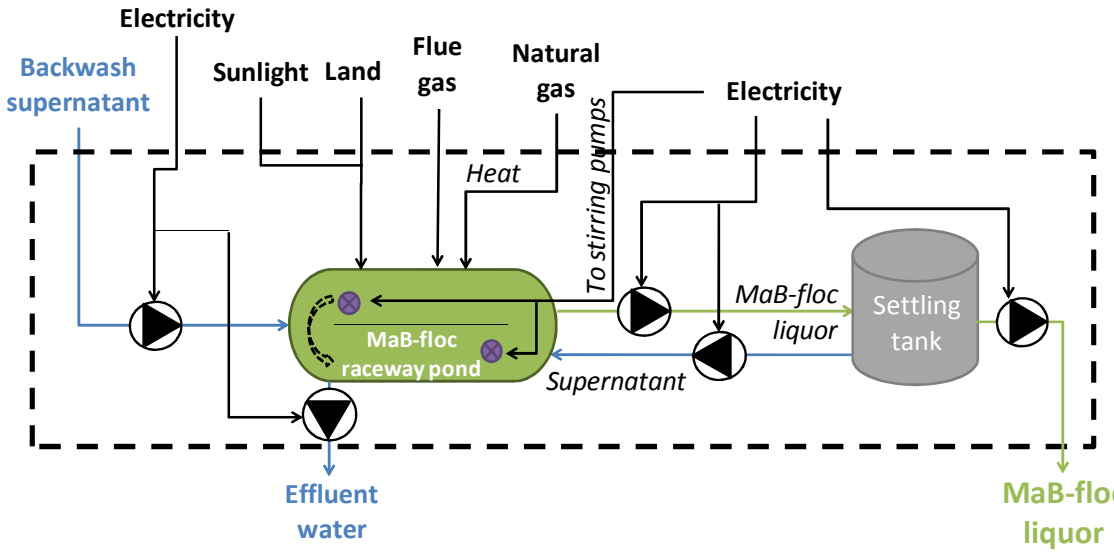
Goal of the study

Goal 1: Assess the environmental footprint of a pilot MaB-floc SBR treating pikeperch culture WW and identify its improvement potential

Goal 2: Forecast the most sustainable valorisation pathway for MaB-flocs in the framework of an integrated aquaculture waste treatment system at industrial scale

Studied MaB-floc based WWT plants

- Pilot MaB-floc SBR treating pikeperch wastewater (real case)

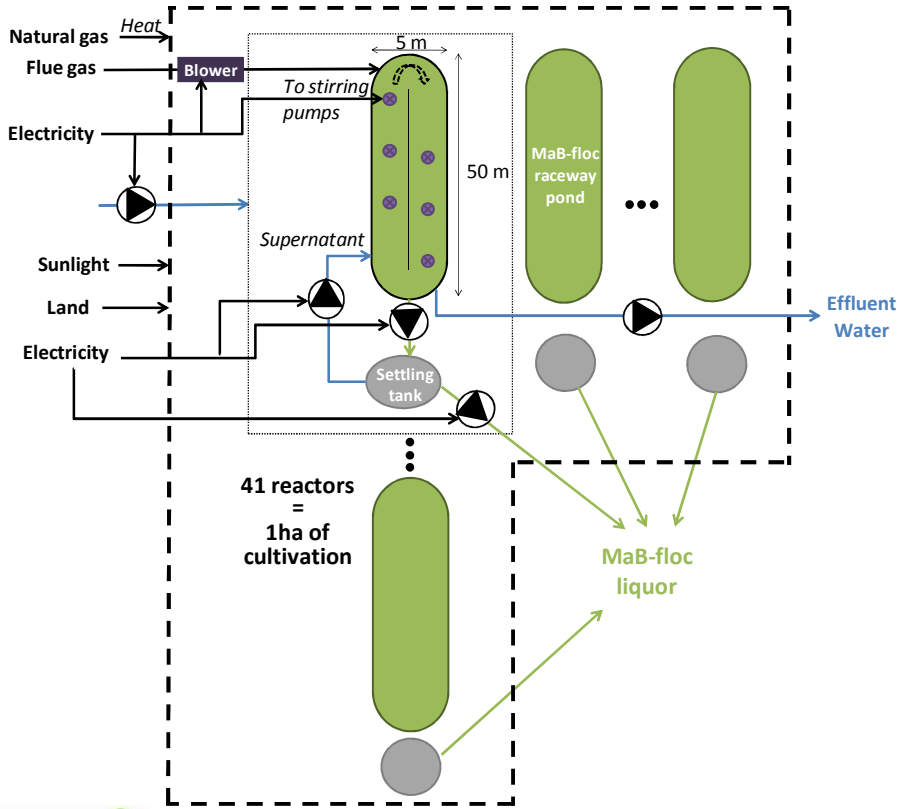


1 pond
Area: 12 m^2
Volume: 28 m^3
Flow: 2.59 m^3 day^{-1}

Van Den Hende 2014

Studied MaB-floc based WWT plants

- Pilot MaB-floc SBR treating pikeperch wastewater (real case)
- Hypothetical up-scaled cases (1000 m^3 of WW treated per day):
  - L: linearly up-scaled MaB-floc plant



41 ponds
Area: 245 m^2 $pond^{-1}$
Volume: 98 m^3 $pond^{-1}$
Flow: 24.5 m^3 day^{-1} $pond^{-1}$

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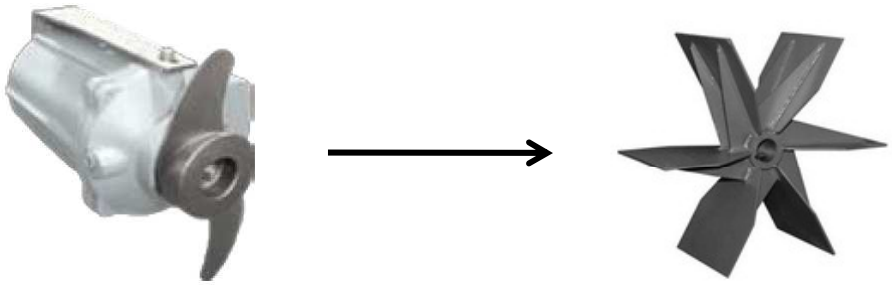
  - L: linearly up-scaled MaB-floc plant
  - S: linearly up-scaled MaB-floc plant with improved stirring system



Propeller pump
22 W m^{-2}

Paddle wheel
5.1 W m^{-2}

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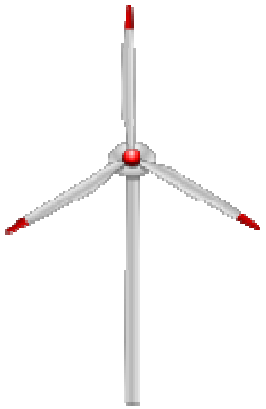
  - E: linearly up-scaled MaB-floc plant with Belgian electricity mix replaced by 100% wind energy



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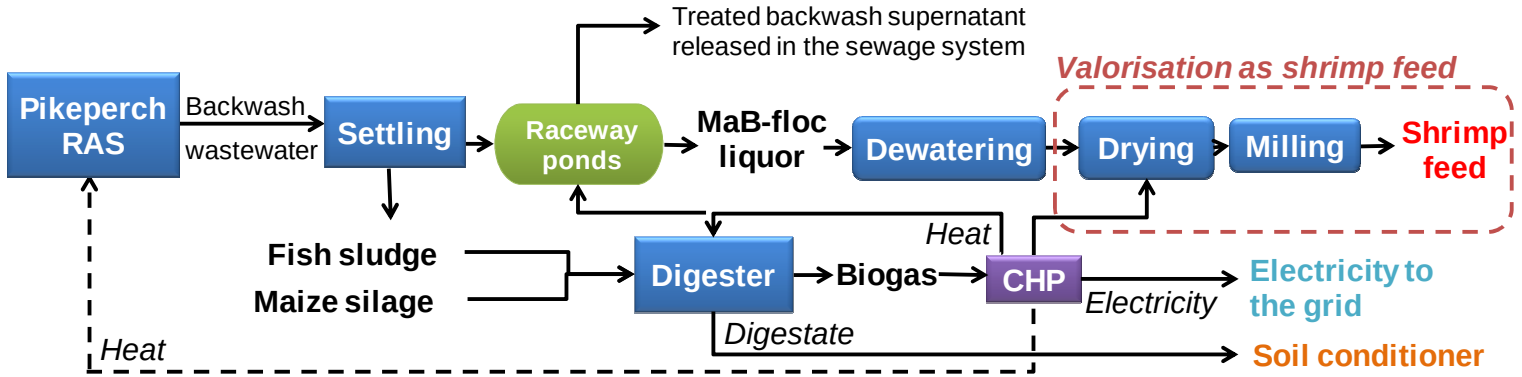
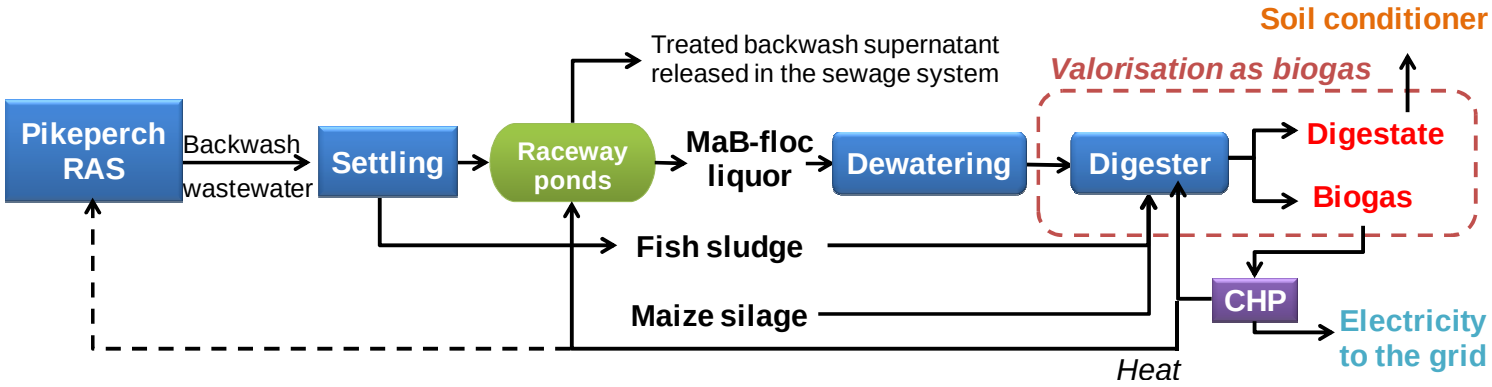
  - E: linearly up-scaled MaB-floc plant with Belgian electricity mix replaced by 100% wind energy
  - M: linearly up-scaled MaB-floc plant with MaB-floc productivity improved by 30%

Studied integrated system

- Three scenarios are compared:
  - Valorisation of MaB-flocs as shrimp feed

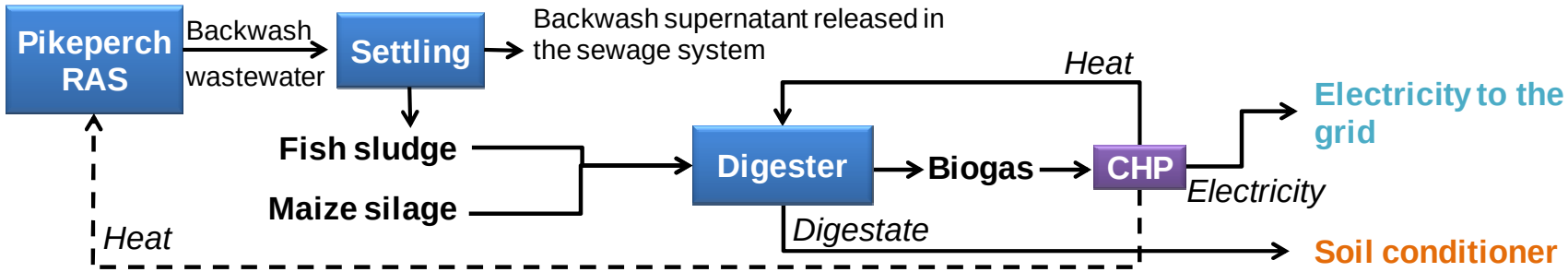


  - Valorisation of MaB-flocs as biogas



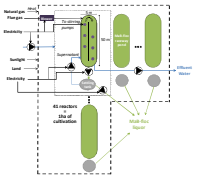
Studied integrated system

- Three scenarios are compared:
  - Valorisation of MaB-flocs as shrimp feed
  - Valorisation of MaB-flocs as biogas
  - Baseline scenario

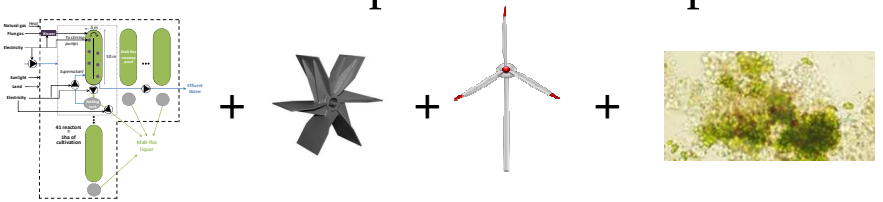


- 2 MaB-flocs plants are integrated:

→ Plant L (linearly up-scaled plant)



→ Plant SEM (plant L with the 3 improvements implemented

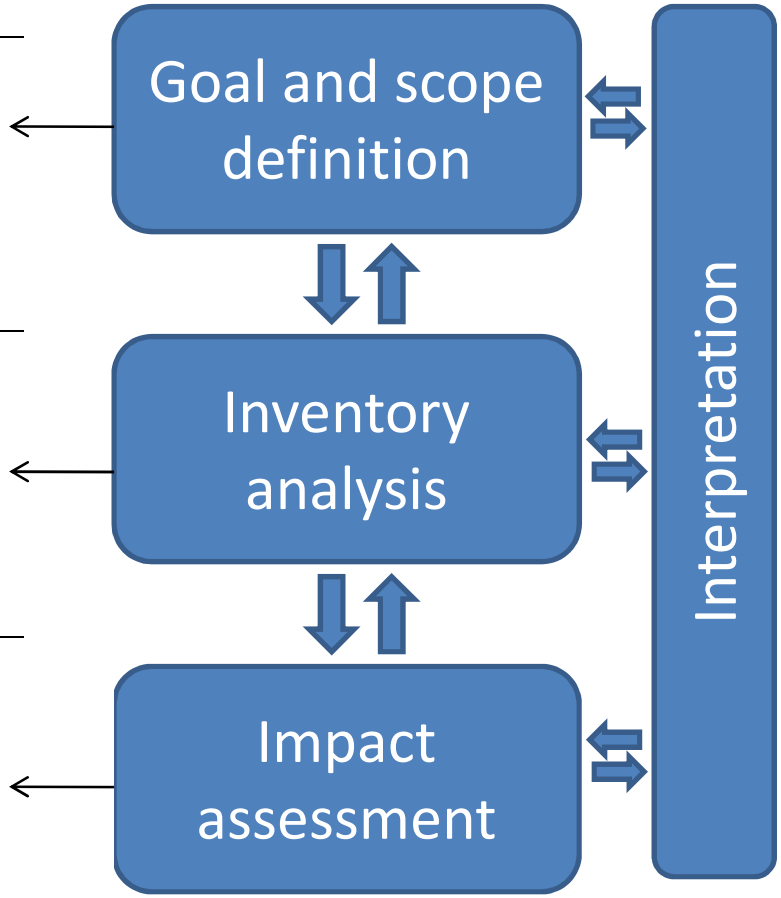


Env. Sustainability Analysis

- Life Cycle Assessment (LCA), ISO standards 14040 & 14044

	Goal 1: comparison of the 4 MaB-floc based WWTP	**Goal 2: SA of the integration of MaB-floc based WWTP in an aquaculture system**
Functional unit	Production of 1 kg TSS MaB-floc liquor	Treatment of 1 m^3 of wastewater
Syst. boundaries	Cradle-to-gate	
Foreground system	Pilot: site data Up-scaled: pilot data + literature	Data from up-scaled plant + ecoinvent v 2.2 + literature
Background system	ecoinvent v 2.2 + literature	

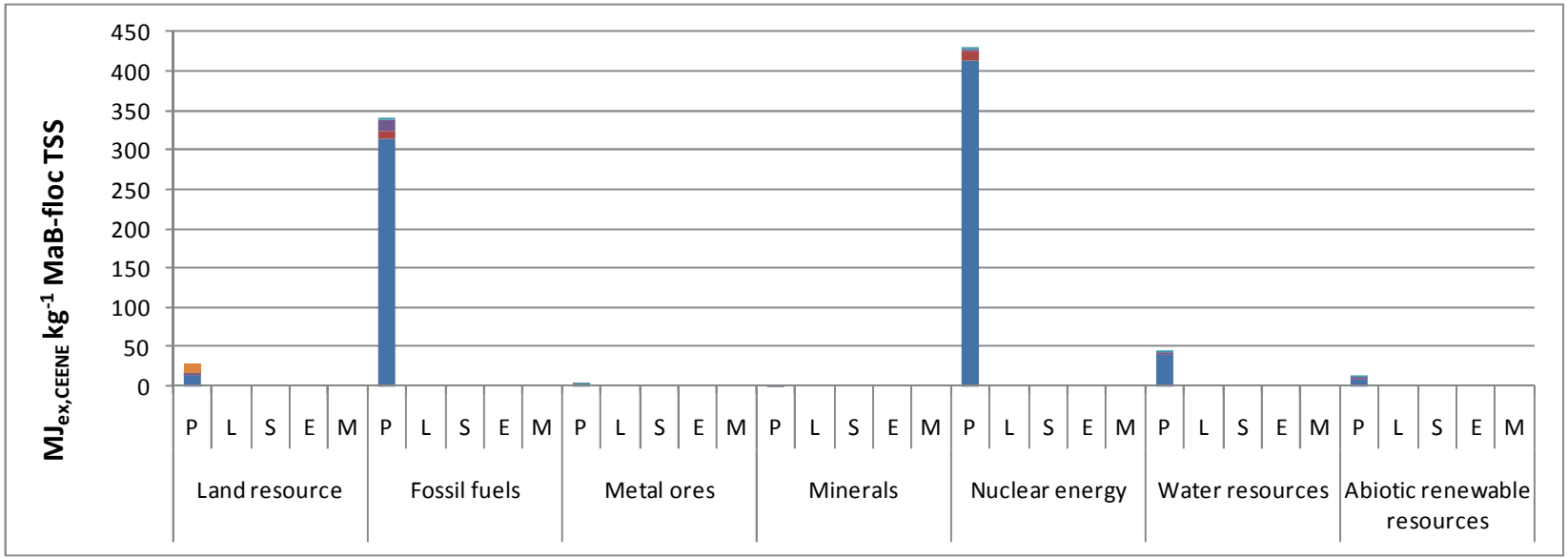
Resource consumption (CEENE 2013)
→ *resource efficiency analysis*
Global warming potential (IPCC 2007)
→ *air emission efficiency analysis*
Marine and freshwater eutrophication (ReCiPe 2013)
→ *water emission efficiency analysis*



LCA results: environmental sustainability of the MaB-floc based WWTP

Resource footprint (CEENE results)

Total CEENE:
848 MJ kg^{-1} MaB-floc TSS

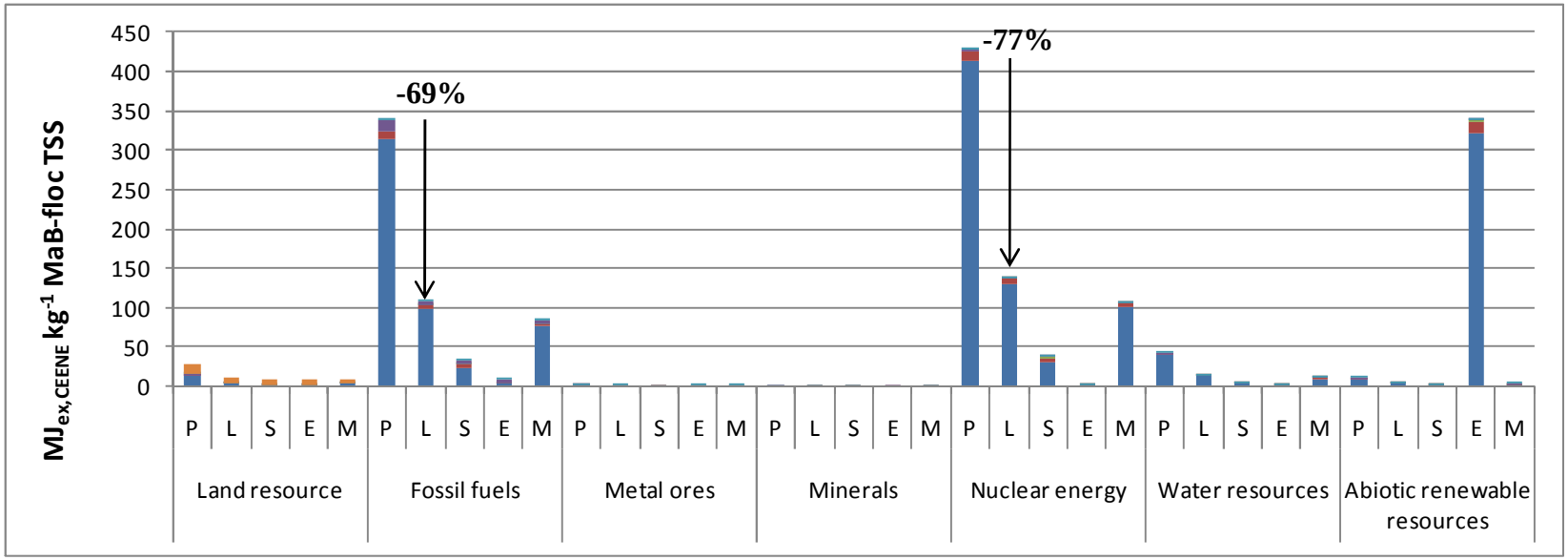


- Electricity consumption - stirring pumps
- Electricity consumption - other pumps
- Electricity consumption - flue gas blower
- Heating of the pond
- Direct Land occupation
- Infrastructure
- Direct phosphorus emissions to water
- Direct nitrogen emissions to water

LCA results: environmental sustainability of the MaB-floc based WWTP

Resource footprint (CEENE results)

Total CEENE plant L: 278 MJ kg^{-1} MaB-floc TSS



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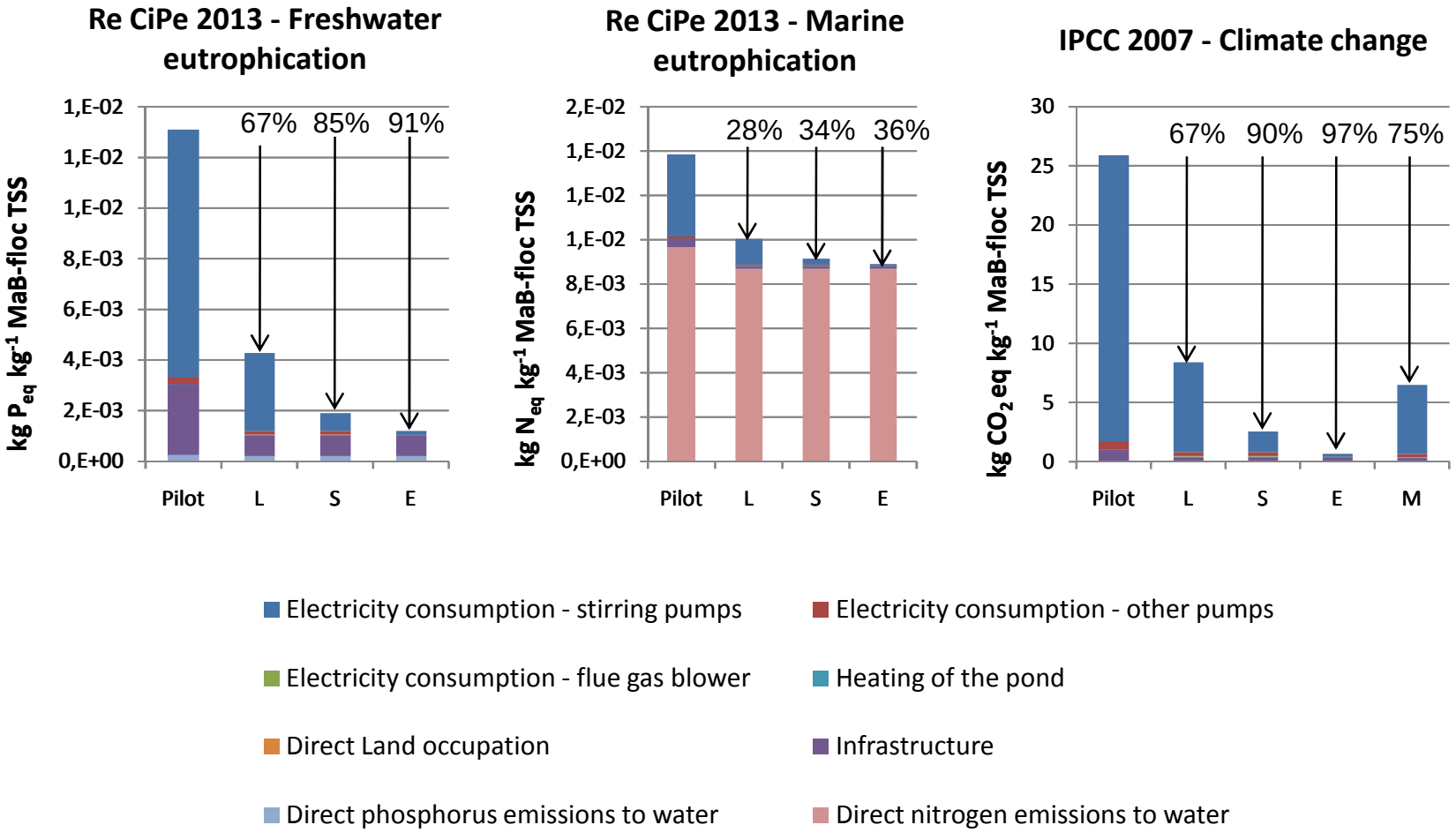
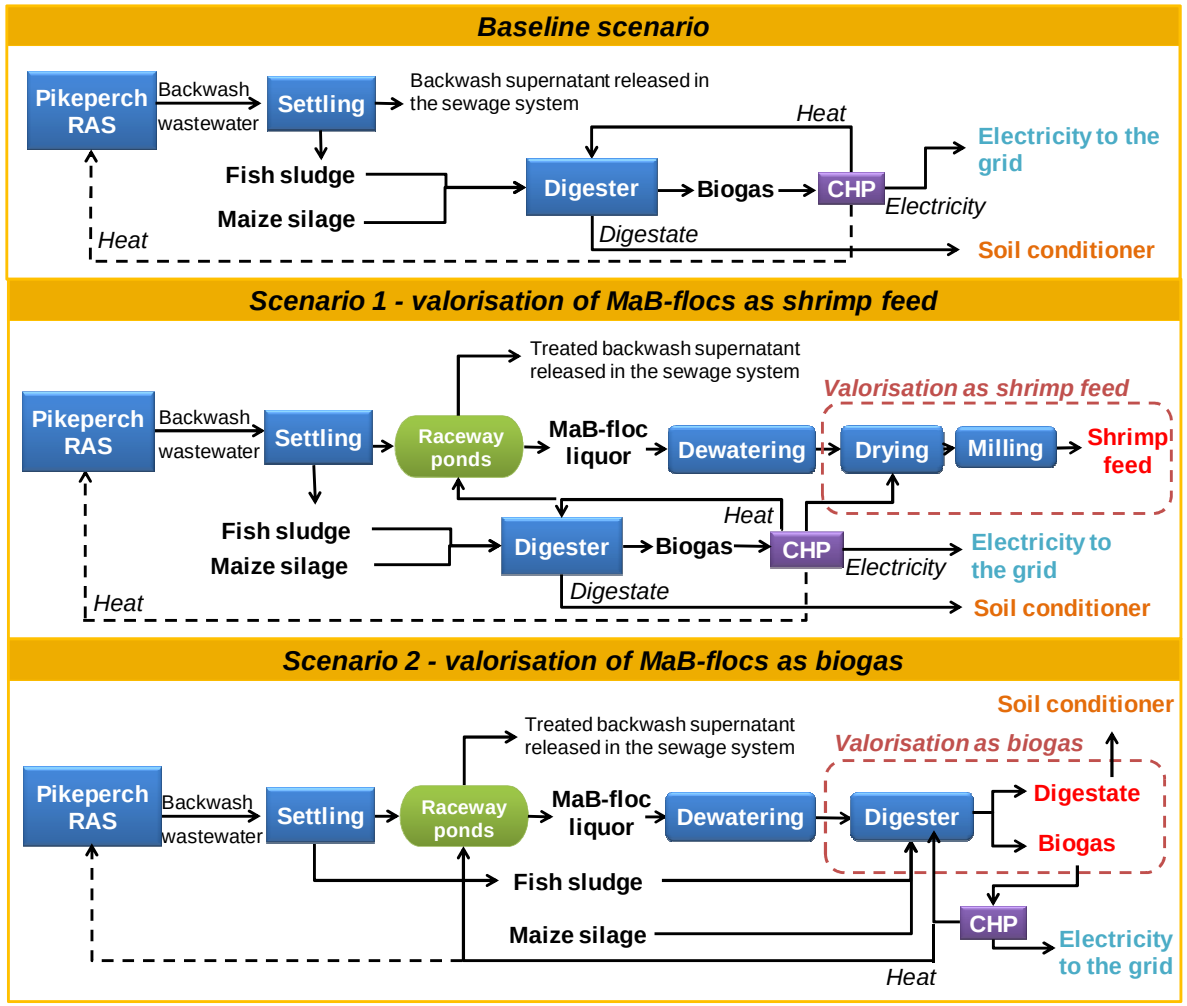


LCA results: environmental sustainability of the Integrated systems



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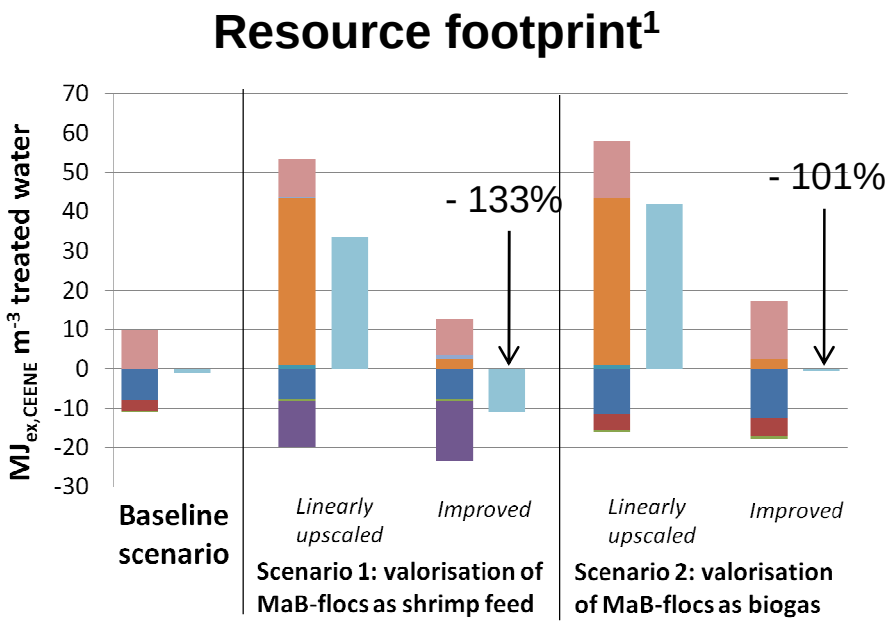


Left bar:

- Phosphorus emission
- Nitrogen emission
- Anaerobic digestion
- Shrimp feed production
- Algae-based wastewater treatment plant
- MaB-flocs dewatering

- Wheat flour (shrimp feed production)
- Compost production (AD)
- Heat production from boiler (AD)
- Electricity from the grid (AD)

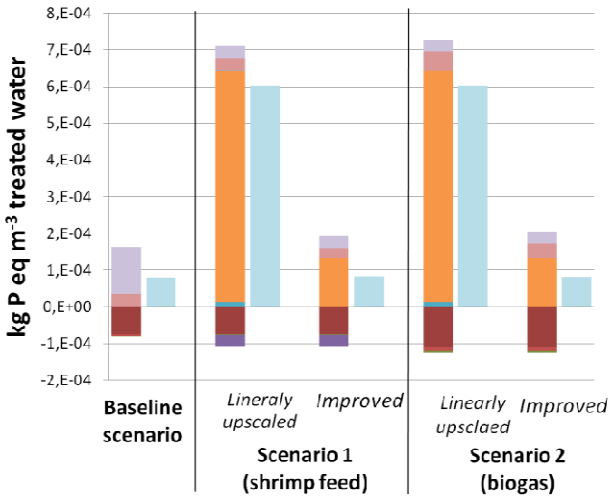
Avoided processes

Right bar: Net impact

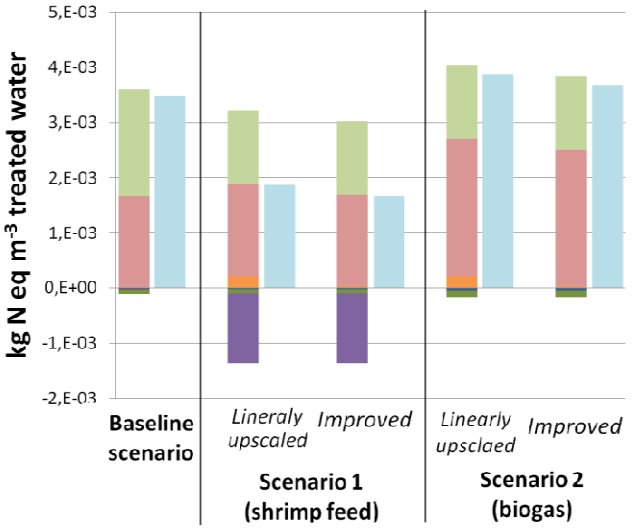
[1] CEENE results without abiotic renewable resources

LCA results: environmental sustainability of the Integrated systems

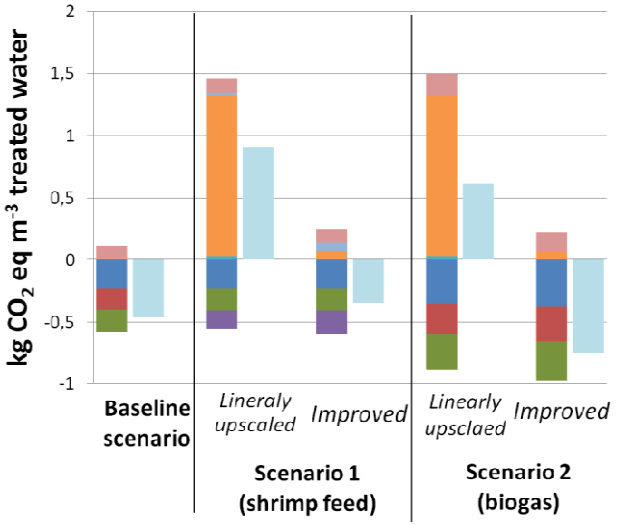
Freshwater eutrophication *(ReCiPe 2013)*



Marine eutrophication *(ReCiPe 2013)*



Carbon footprint *(IPCC 2007)*



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Right bar: Net impact

Avoided processes
- Wheat flour (shrimp feed production)
- Compost production (AD)
- Heat production from boiler (AD)
- Electricity from the grid (AD)

Conclusion

- MaB-floc technology: stirring has the highest contribution to most impact categories
- Integrated aquaculture waste treatment system:
  - Potential to compete with the baseline scenario and contribute to a sustainable connection of the water-food-energy nexus in the aquaculture sector
  - Valorizing MaB-flocs into shrimp feed: overall more sustainable than into biogas

Bottleneck: EU legislation

- Future research:
  - Improvement of LCA with more complete data on nutrient cycle (measurements needed)
  - Focus on the improvement of the energy efficiency of the system, rather than of MaB-flocs productivity

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Thank you!

Sophie.Sfez@UGent.be
+32 (0) 9 264 99 27

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www.enalgae.eu info@enalgae.eu

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